



US009168654B2

(12) **United States Patent**
Briggs et al.

(10) **Patent No.:** **US 9,168,654 B2**
(45) **Date of Patent:** **Oct. 27, 2015**

(54) **COORDINATE MEASURING MACHINES
WITH DUAL LAYER ARM**

USPC 33/503
See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 499 days.

(21) Appl. No.: **13/486,673**

(22) Filed: **Jun. 1, 2012**

(65) **Prior Publication Data**

US 2013/0205606 A1 Aug. 15, 2013

Related U.S. Application Data

(60) Continuation-in-part of application No. 29/412,903, filed on Feb. 9, 2012, now Pat. No. Des. 676,341, which is a division of application No. 29/379,170, filed on Nov. 16, 2010, now Pat. No. Des. 662,427.

(51) **Int. Cl.**

G01B 5/008 (2006.01)
G01B 1/00 (2006.01)
B25J 9/00 (2006.01)
G01B 11/00 (2006.01)
B29D 23/00 (2006.01)

(52) **U.S. Cl.**

CPC **B25J 9/0012** (2013.01); **G01B 1/00** (2013.01); **G01B 5/008** (2013.01); **G01B 11/005** (2013.01); **B29D 23/001** (2013.01)

(58) **Field of Classification Search**

CPC G01B 5/004; G01B 5/008; G01B 1/00; G01B 11/00

Primary Examiner — Richard A Smith

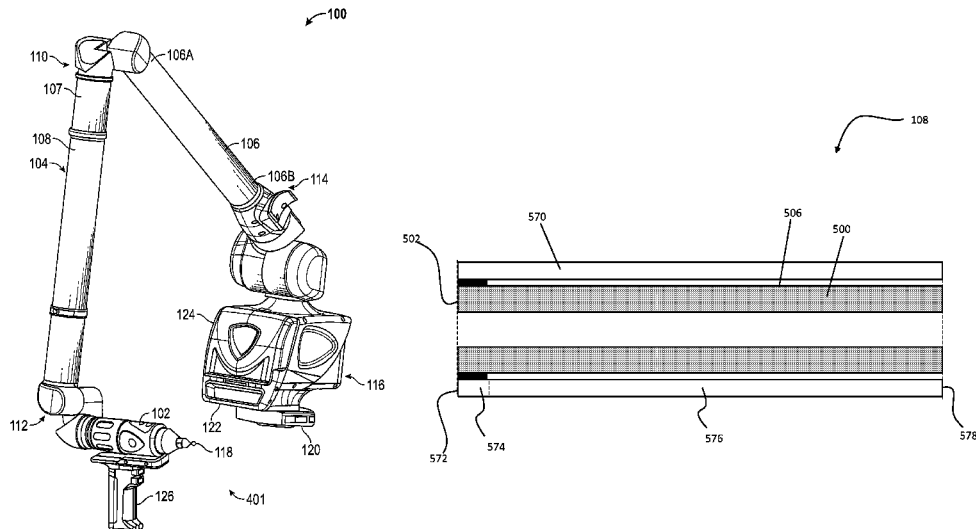
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(57)

ABSTRACT

A portable articulated arm coordinate measuring machine (AACMM) is provided including a manually positionable articulated arm having opposed first and second ends. The arm includes multiple connected arm segments. Each arm segment has a longitudinal axis. Each arm segment includes a generally tubular core, an outer sleeve surrounding at least a portion of a length of the core, and at least one position transducer for producing a position signal. The outer sleeve is a cylindrical tube having a first portion at a first end and a second portion that extends from the first portion to an opposite end. The first portion is coupled to an end of the core. The first portion is shorter than the second portion and the second portion is configured to move relative to the core.

26 Claims, 13 Drawing Sheets



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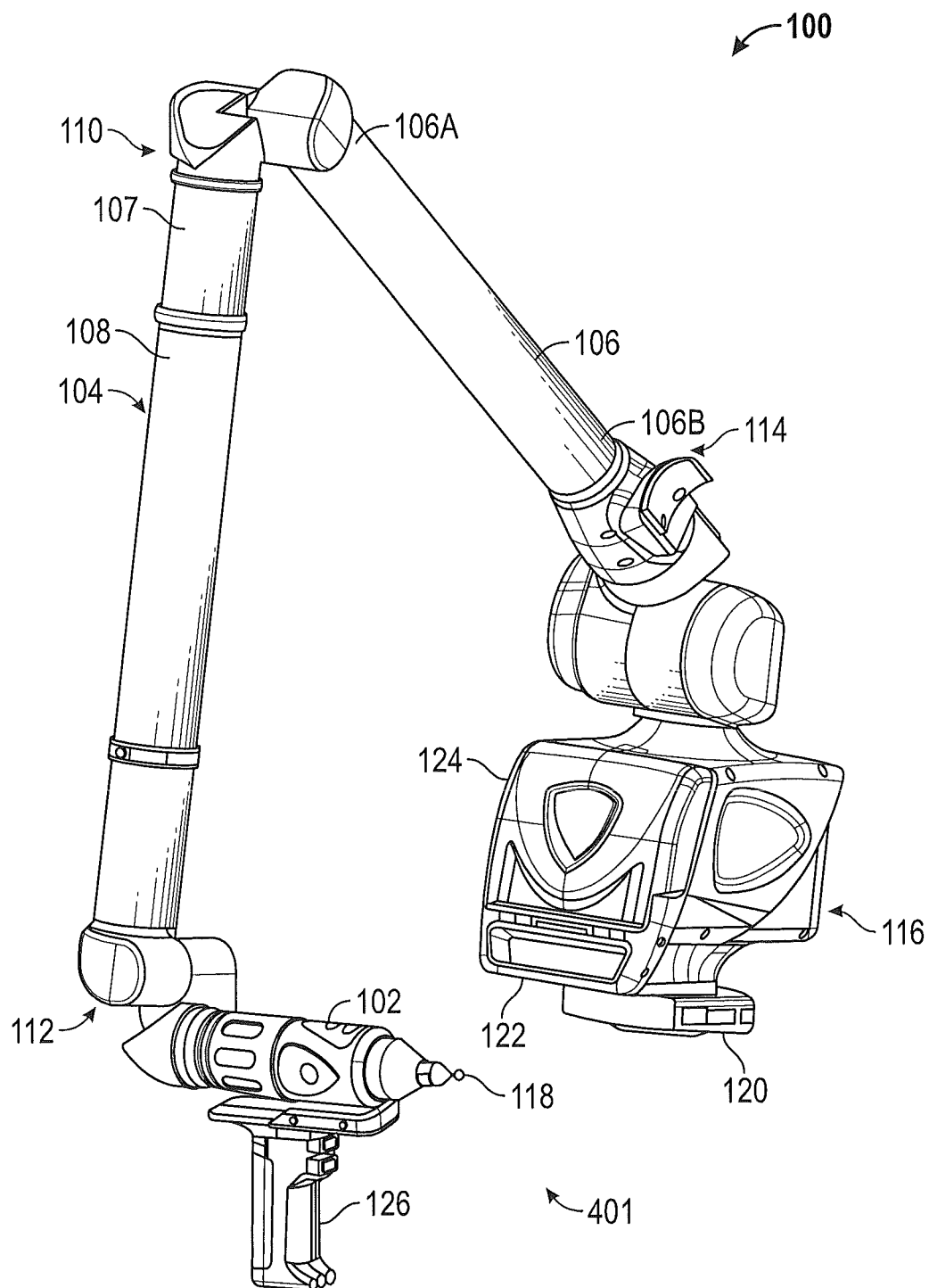


FIG. 1A

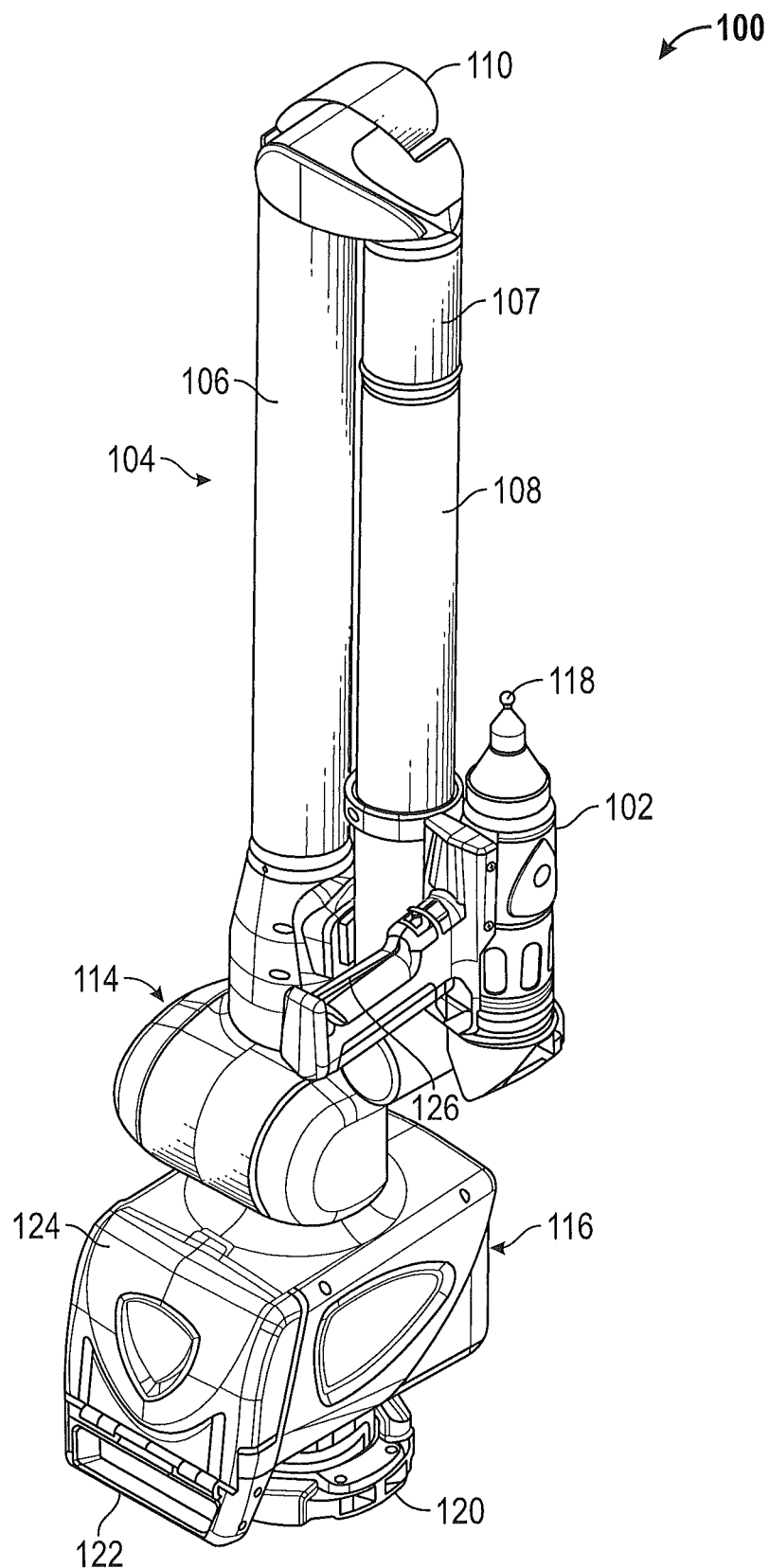


FIG. 1B

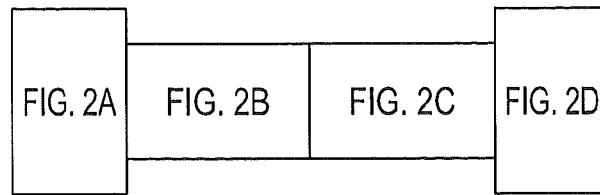


FIG. 2

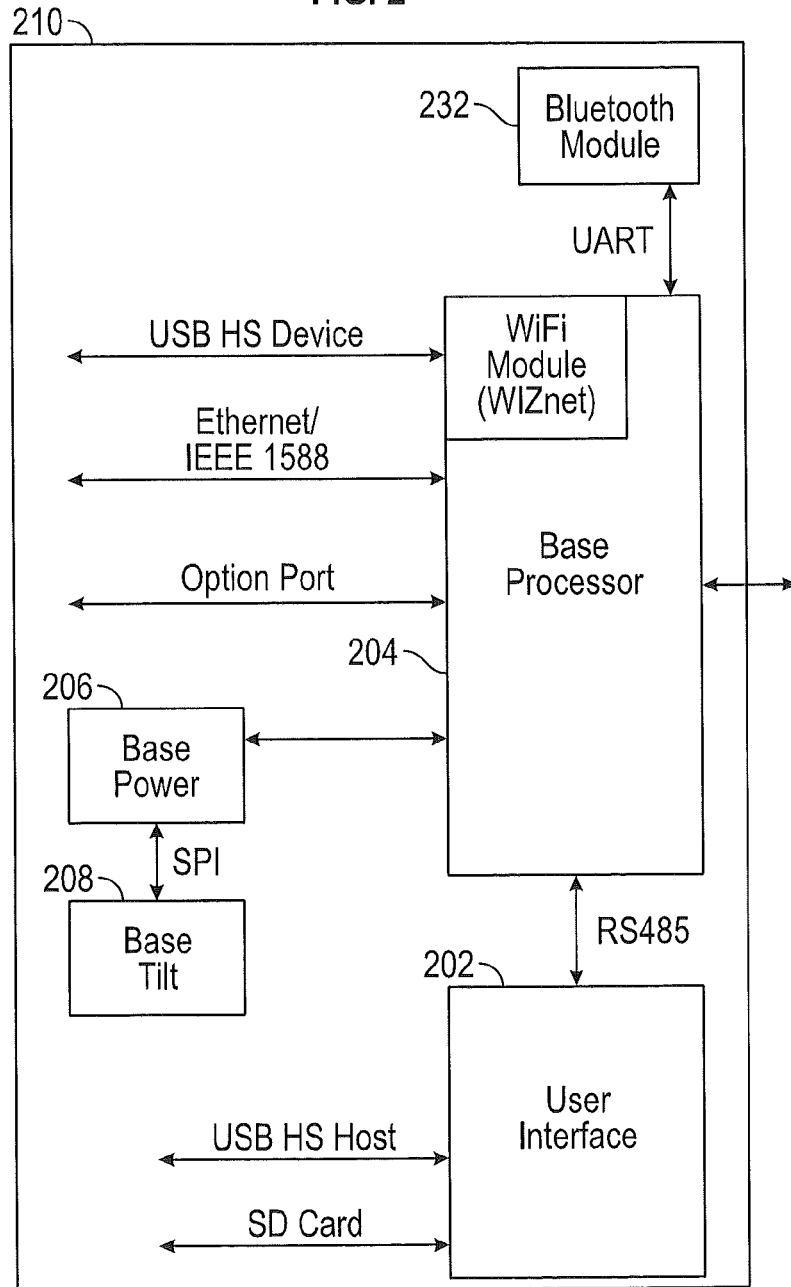


FIG. 2A

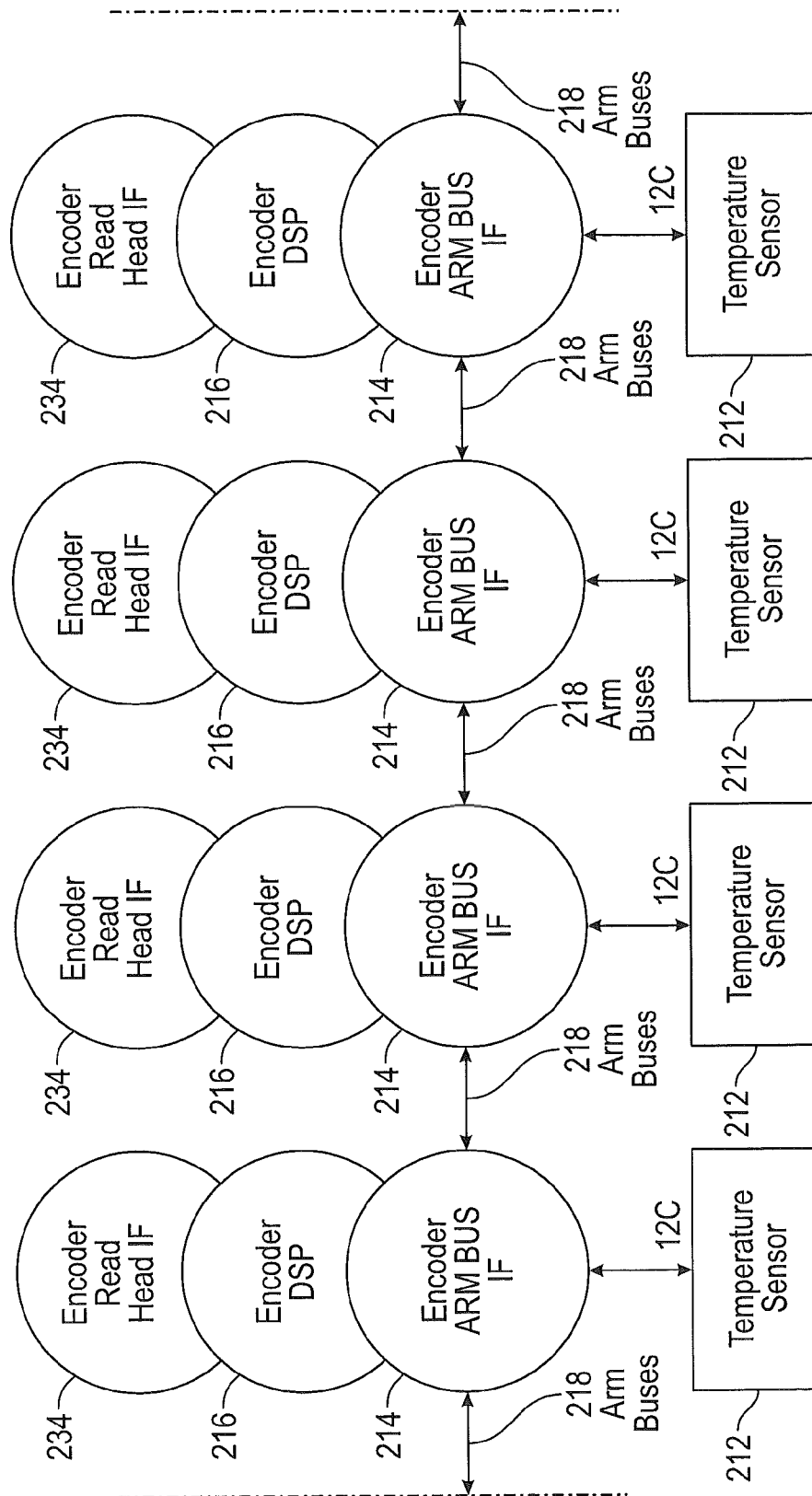


FIG. 2B

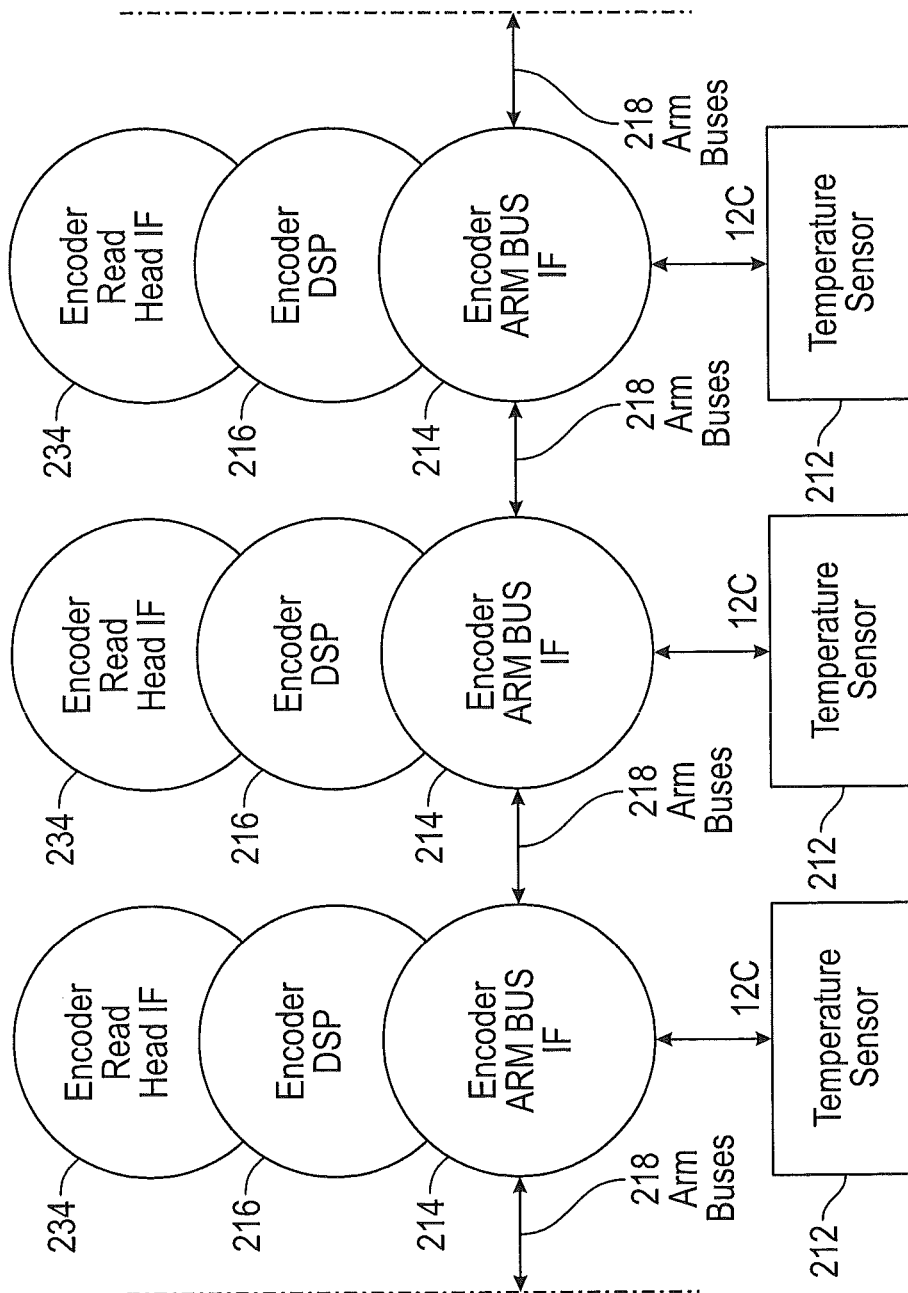


FIG. 2C

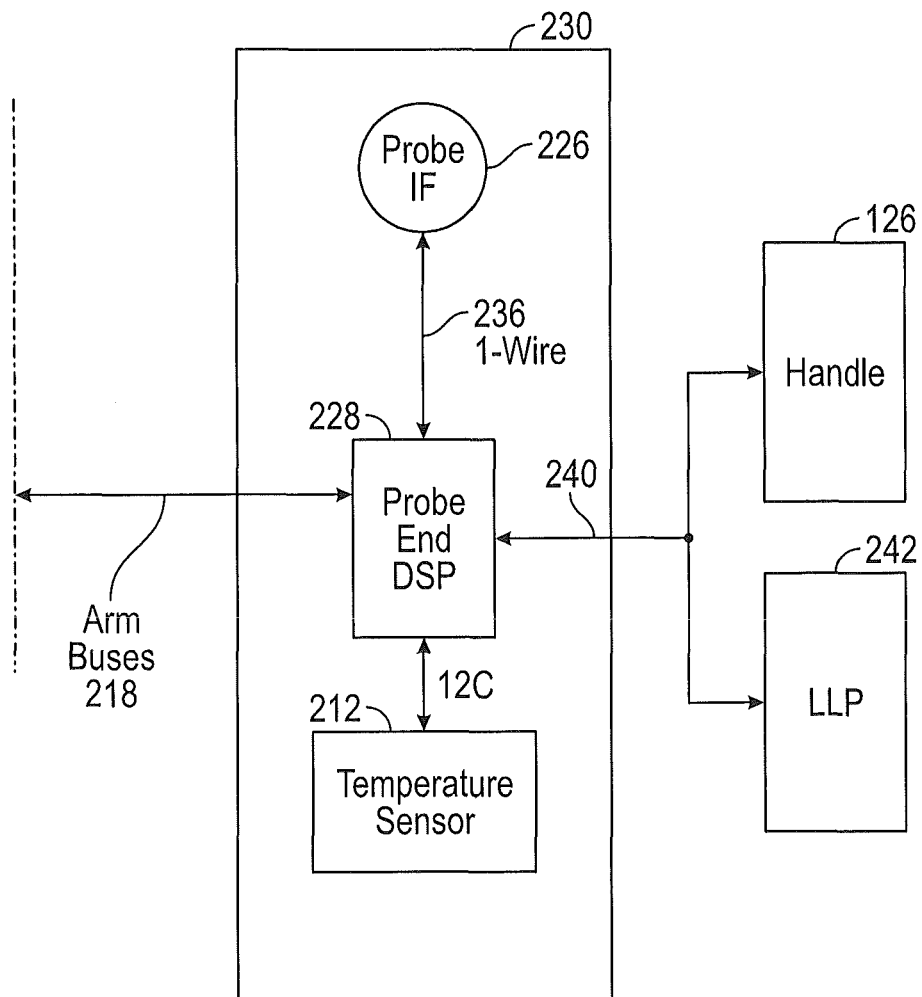
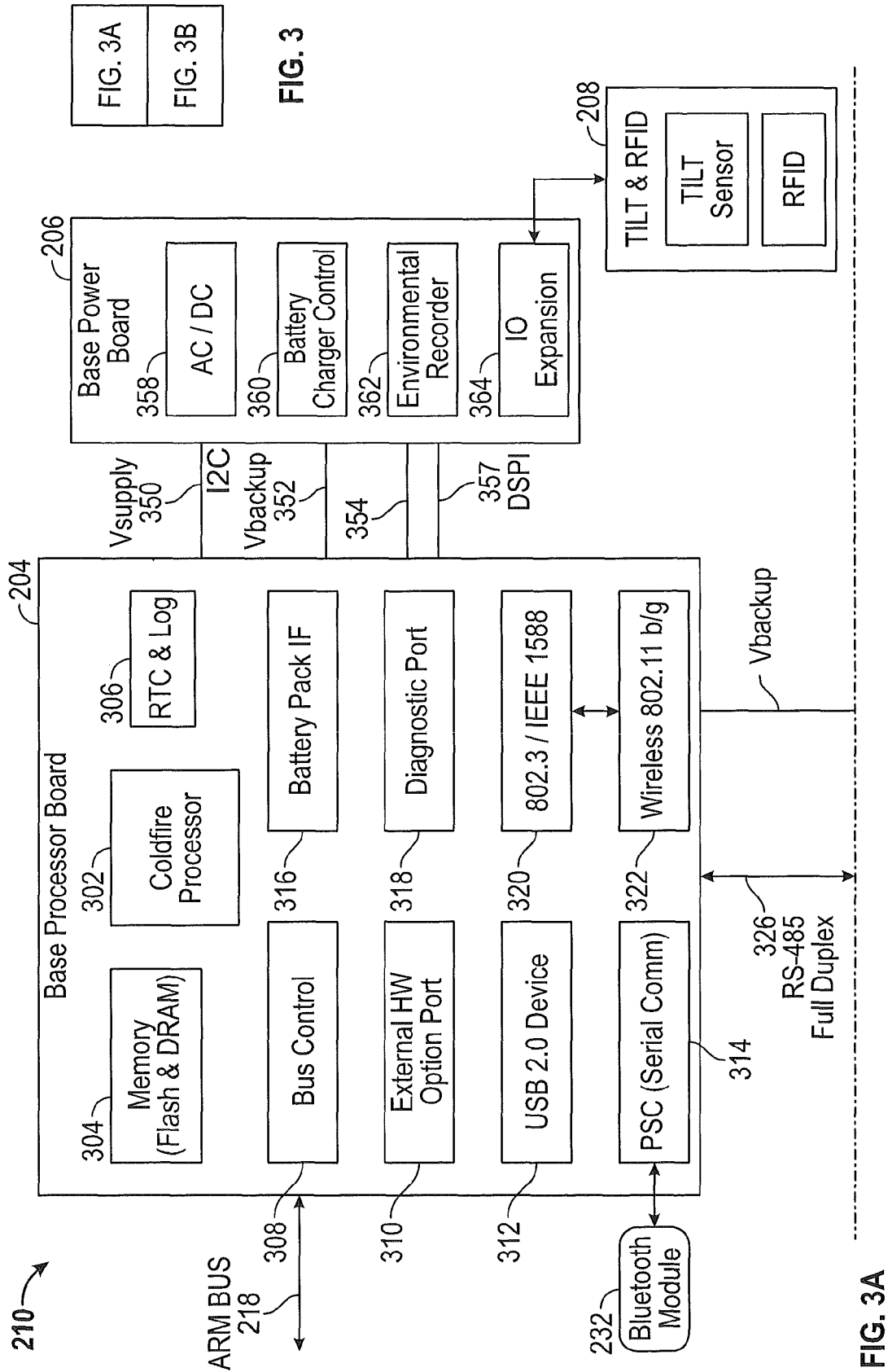


FIG. 2D



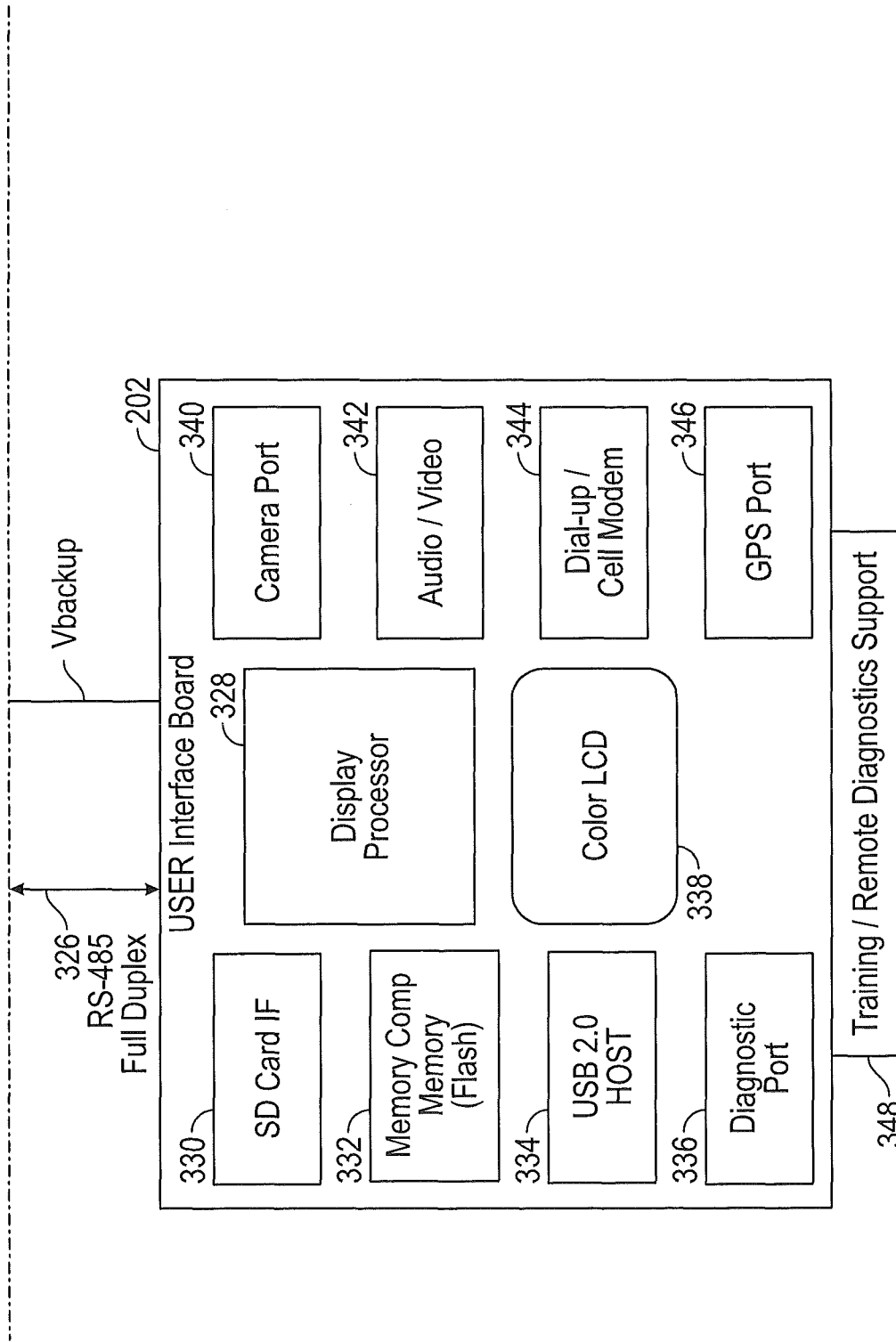


FIG. 3B

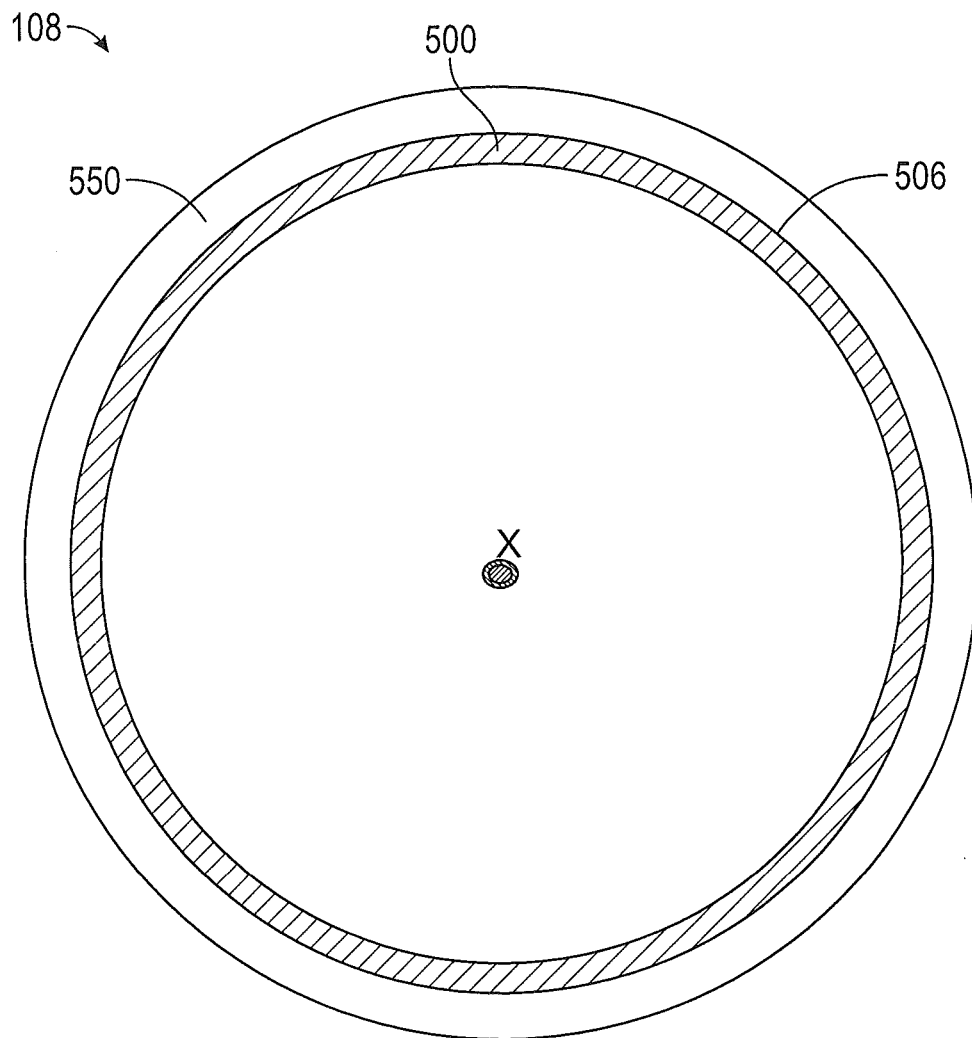


FIG. 4

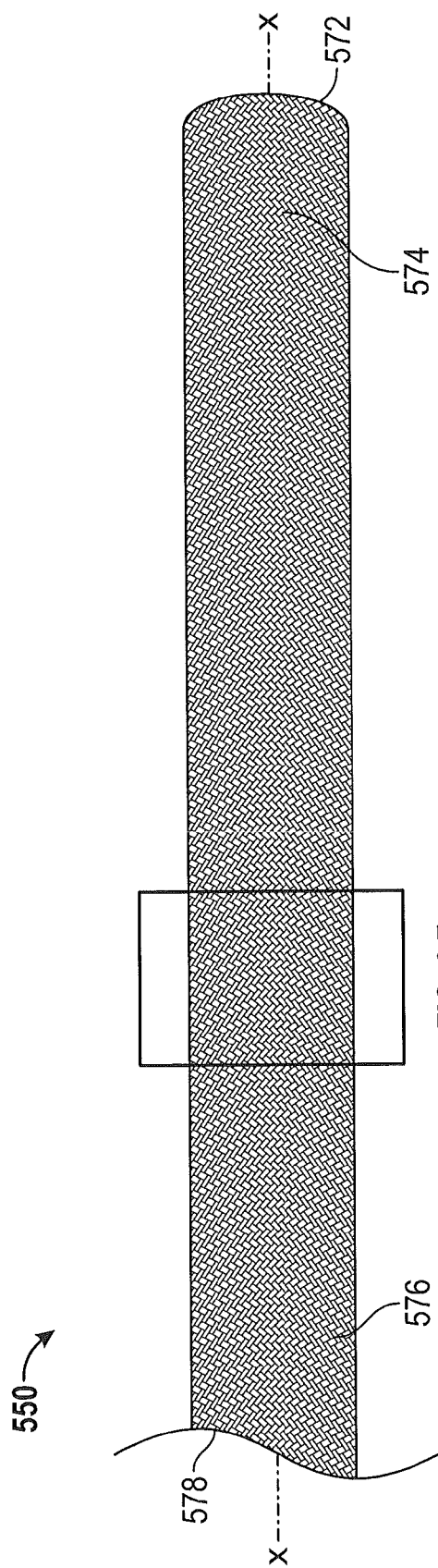


FIG. 6,7

FIG. 5

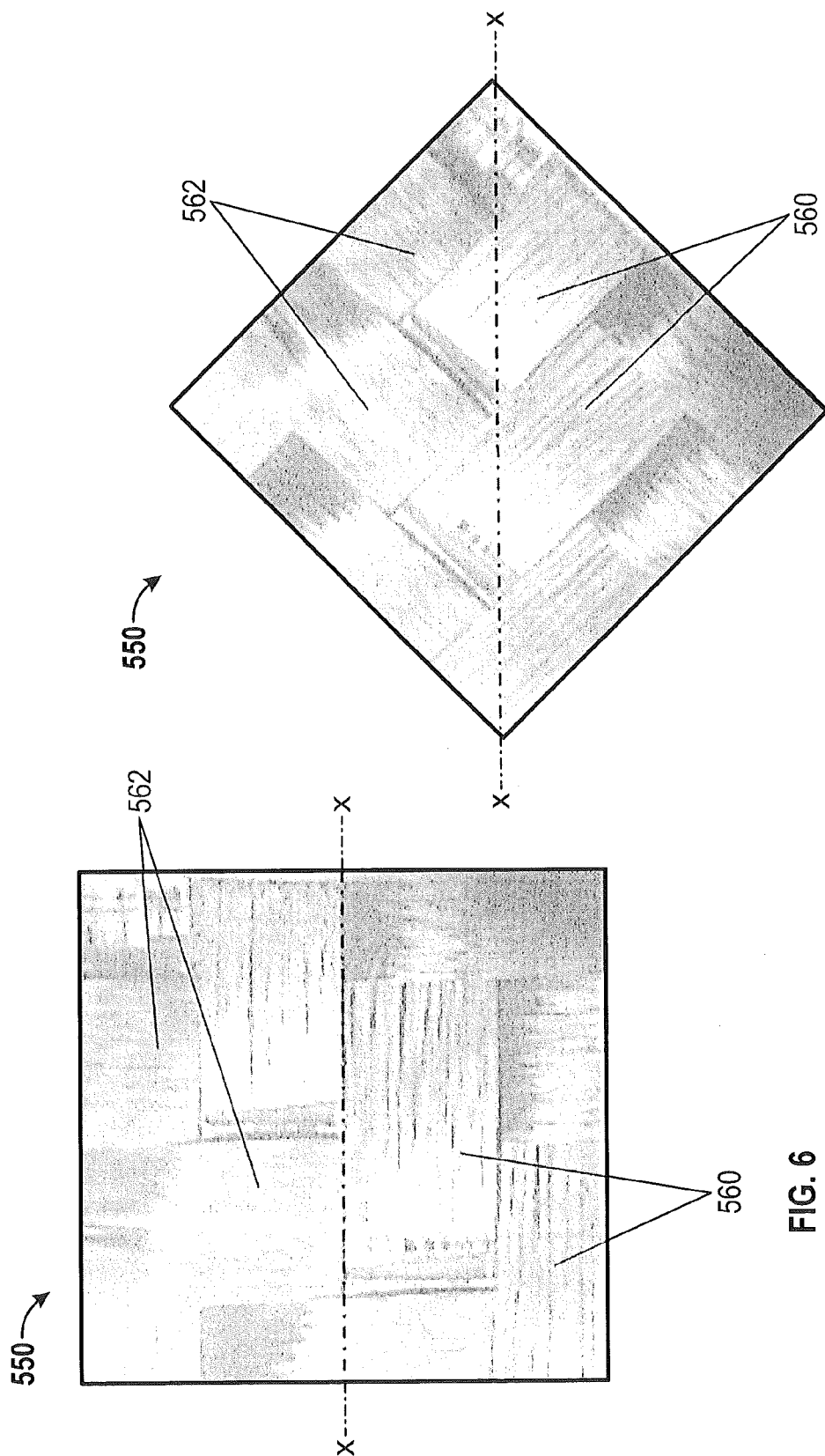


FIG. 7

FIG. 6

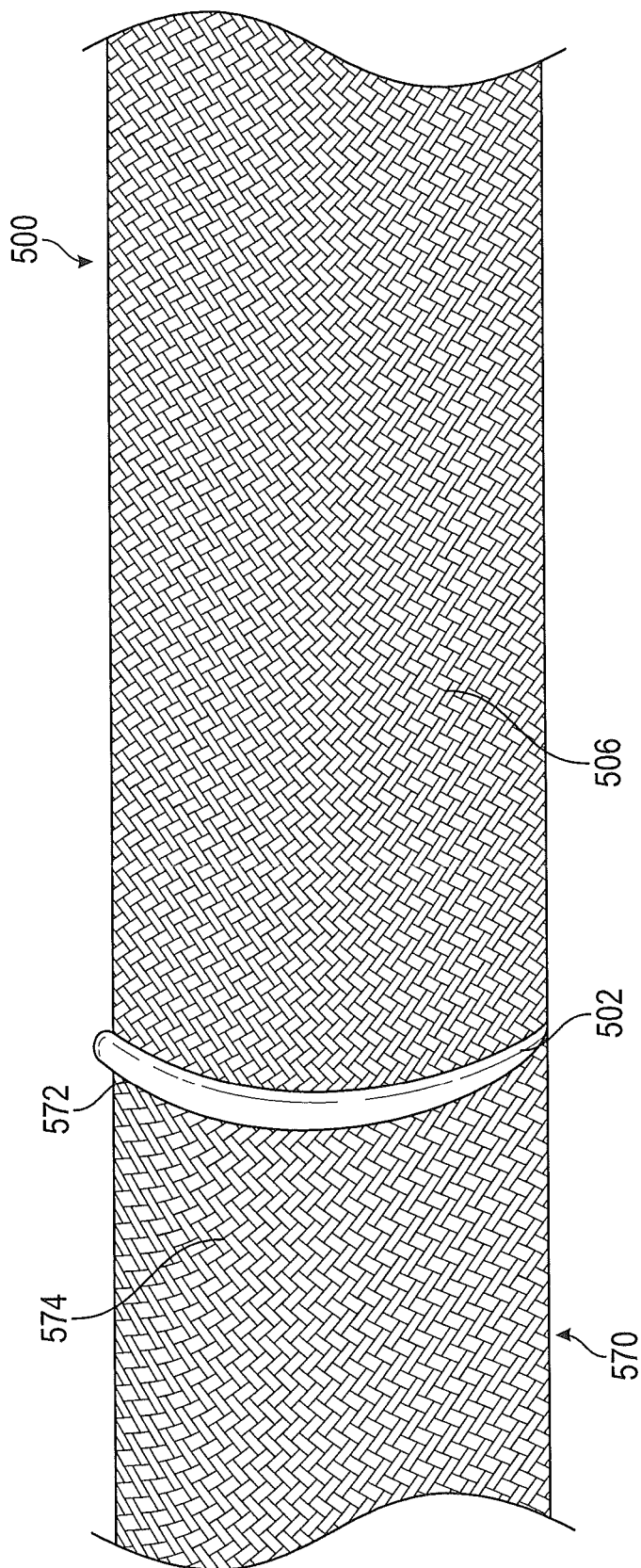


FIG. 8

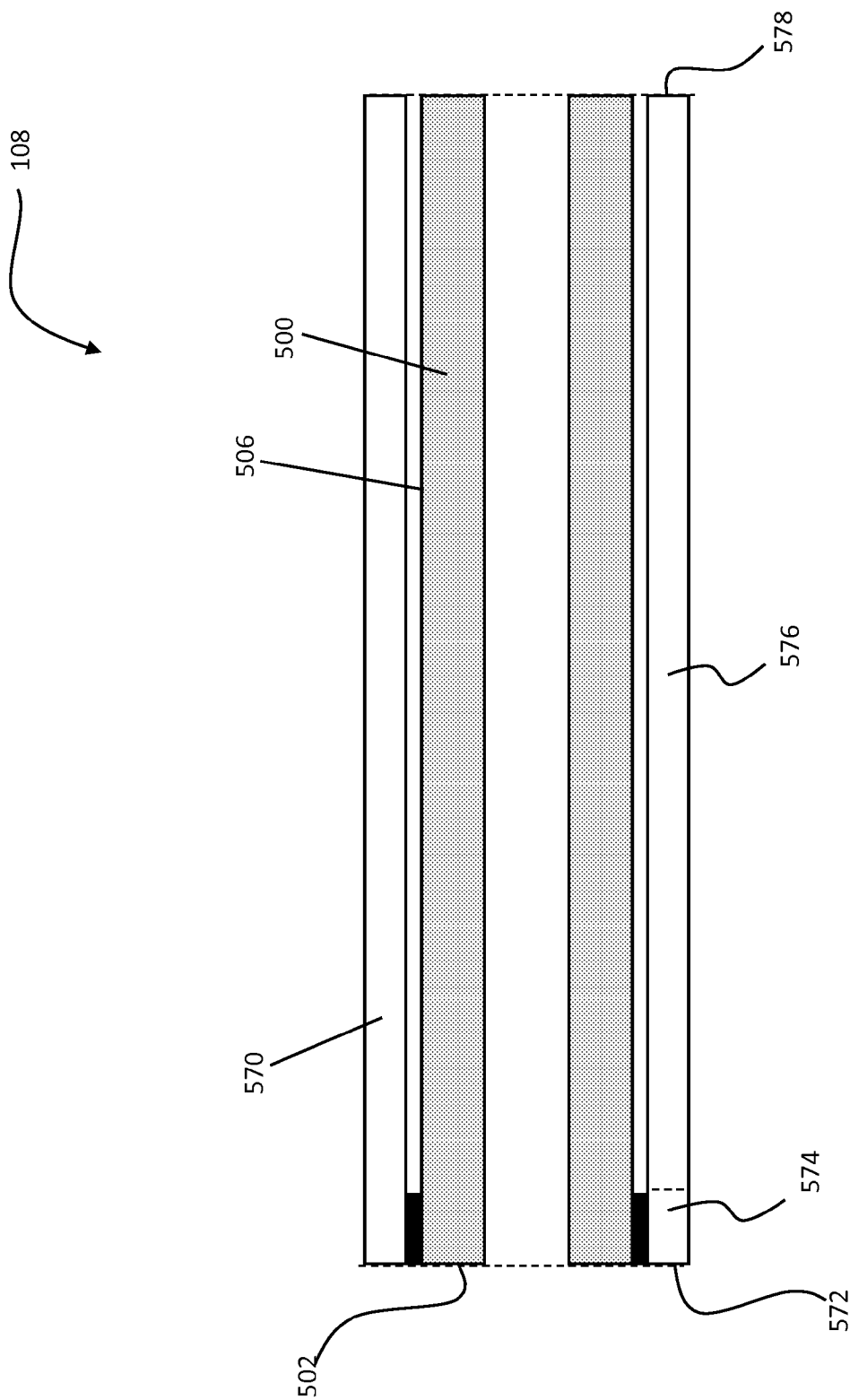


FIG. 9

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COORDINATE MEASURING MACHINES WITH DUAL LAYER ARM

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Design Application No. 29/412,903, filed Feb. 9, 2012 and U.S. Design Application No. 29/379,170, filed Nov. 16, 2010 the entire contents of each of which are incorporated herein by reference.

BACKGROUND

The present disclosure relates to a coordinate measuring machine and, more particularly, to an arm of a portable articulated coordinate measuring machine.

Portable articulated arm coordinate measuring machines (AACMMs) have found widespread use in the manufacturing or production of parts where there is a need to rapidly and accurately verify the dimensions of the part during various stages of the manufacturing (e.g. machining) or production of the part. Portable AACMMs represent a vast improvement over known stationary or fixed, cost-intensive, and relatively difficult to use measurement installations, particularly in the amount of time it takes to perform dimensional measurements of relatively complex parts. Typically a user of a portable AACMM simply guides a probe along the surface of the part or object to be measured. The measurement data are then recorded and provided to the user. In some cases, the data are provided to the user in visual form, for example, three dimensional (3-D) form on a computer screen. Alternatively, the data may be provided to the user in numeric form, for example, when measuring the diameter of a hole, the text "Diameter=" is displayed on a computer screen.

Arm portions of AACMMs may be susceptible to twist due to temperature changes. Twisting of a portion of an arm segment may cause a coupled encoder to rotate, thereby generating an angle error and reducing the accuracy of the machine. Such a twisting may be caused for example by a patterned composite material on an outer region of the arm segment, the outer region having a non-uniform pattern. In general, such twisting effects cannot be removed by measuring temperatures, especially since temperature sensors are ordinarily located in the interior of the arm segments. A method is needed to minimize twisting of the arm segments.

SUMMARY

According to one embodiment of the invention, a portable articulated arm coordinate measuring machine (AACMM) is provided including a manually positionable articulated arm having opposed first and second ends. The arm includes a plurality of connected arm segments. Each arm segment has a longitudinal axis. Each arm segment includes a generally tubular core, an outer sleeve surrounding at least a portion of a length of the core, and at least one position transducer for producing a position signal. The outer sleeve is a cylindrical tube having a first portion at a first end and a second portion that extends from the first portion to an opposite end. The first portion is coupled to an end of the core. The first portion is shorter than the second portion and the second portion is configured to move relative to the core. The portable AACMM also includes a measurement device attached to a first end. An electronic circuit receives the position signal from the at least one transducer and provides data corresponding to a position of the measurement device.

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According to another embodiment of the invention, a portable AACMM is provided including a manually positionable articulated arm having opposed first and second ends. The arm includes a plurality of connected arm segments. Each arm segment has a longitudinal axis and includes a core surrounded by an outer material and at least one position transducer for producing a position signal. The outer material includes a plurality of first fibers arranged orthogonally to a plurality of second fibers. The plurality of first fibers and the plurality of second fibers are oriented relative to a longitudinal axis of the arm segment. The AACMM also includes a measurement device attached to a first end of the AACMM and an electronic circuit. The electronic circuit receives a position signal from the at least one position transducer and provides data corresponding to a position of the measurement device.

According to another embodiment of the invention, a method is provided for forming an arm segment for a portable AACMM including forming a generally hollow cylindrical core having a longitudinal axis from a first material. The first material includes a plurality of first fibers arranged orthogonally to a plurality of second fibers. A tubular sleeve is formed from a second material. The second material includes a plurality of third fibers arranged orthogonally to a plurality of fourth fibers. The plurality of third fibers and the plurality of fourth fibers are in a desired orientation relative to the axis. The core is inserted into the sleeve and a first end of the sleeve is fastened to a first end of the core.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, exemplary embodiments are shown which should not be construed to be limiting regarding the entire scope of the disclosure, and wherein the elements are numbered alike in several FIGURES:

FIG. 1, including FIGS. 1A and 1B, are perspective views of a portable articulated arm coordinate measuring machine (AACMM) having embodiments of various aspects of the present invention therewithin;

FIG. 2, including FIGS. 2A-2D taken together, is a block diagram of electronics utilized as part of the AACMM of FIG. 1 in accordance with an embodiment of the present invention;

FIG. 3, including FIGS. 3A and 3B taken together, is a block diagram describing detailed features of the electronic data processing system of FIG. 2 in accordance with an embodiment of the present invention;

FIG. 4 is a perspective view of an end of an arm segment according to an embodiment of the present invention;

FIG. 5 is a top view of a portion of an arm segment according to an embodiment of the present invention;

FIG. 6 is a perspective view of a portion of an arm segment according to an embodiment of the invention;

FIG. 7 is a perspective view of a portion of an arm segment according to an embodiment of the invention; and

FIG. 8 is a perspective view of a portion of an arm segment according to an embodiment of the invention;

FIG. 9 is a cross-sectional view of an arm segment according to an embodiment of the present invention.

DETAILED DESCRIPTION

FIGS. 1A and 1B illustrate, an exemplary portable articulated arm coordinate measuring machine (AACMM) according to various embodiments of the present invention, and articulated arm being one type of coordinate measuring machine. AACMMs are used in a variety of applications to obtain measurements of objects. The AACMM 100 may

include a six or seven axis articulated measurement device having a probe end **401** that includes a measurement probe housing **102** coupled to an arm portion **104** of the AACMM **100** at one end. The arm portion **104** comprises a first arm segment **106** coupled at a first end **106a** to a second arm segment **108** by a first grouping of bearing cartridges **110** (e.g. two bearing cartridges). A second grouping of bearing cartridges **112** (e.g. two bearing cartridges) couples the second arm segment **108** to the measurement probe housing **102**. A third grouping of bearing cartridges **114** (e.g. three bearing cartridge) couples the second end **106b** of the first arm segment **106** to a base **116**. A bearing cartridge, as used herein, allows a component coupled to the bearing cartridge to move independently about an axis. When combined into a group **110**, **112**, **114**, the bearing cartridges may form a hinge and swivel type of connector such that an adjoining component is independently movable about two axes. It should be appreciated that bearing cartridges may be grouped together in different configurations to form a connector movable about a single axis or a plurality of axes. The measurement probe housing **102** may comprise the shaft of an additional axis of the AACMM **100** (e.g. a cartridge containing an encoder system that determines movement of the measurement device, for example a probe **118**, of the AACMM **100**.) In this embodiment, the probe end **401** may rotate about an axis extending through the center of measurement probe housing **102**. In use of the AACMM **100**, the base **116** is typically affixed to a planar work surface.

Each bearing cartridge within each bearing cartridge grouping **110**, **112**, **114** typically contains an encoder system (e.g. an optical angular encoder system). The encoder system provides an indication of the position of the respective arm segments **106**, **108** and the corresponding bearing cartridge groupings **110**, **112**, **114** that together provide an indication of the position of the probe **118** with respect to the base **116**. A portable AACMM having multiple axes of articulated movement, such as six or seven for example, provides advantages in allowing the operator to position the probe **118** in a desired location within a **360** degree area about the base, while providing an arm portion **104** that may be easily maneuvered by an operator. It should be appreciated that the illustrated arm portion **104** having a first arm segment **106** coupled to a second arm segment **108** is for illustrative purposes only and the claimed invention should not be so limited. An AACMM **100** according to the invention may include any number of arm segments coupled together by bearing cartridges, and thus, more or less than six or seven axes of articulated movement or degrees of freedom.

The probe **118** is detachably mounted to the measurement probe housing **102**, which is connected to the bearing cartridge grouping **112**. A handle **126** is removable with respect to the measurement probe housing **102** by way of, for example, a quick connect interface. The handle **126** may be replaced with another device (e.g. a laser line probe, a bar code reader, etc. . . .), thereby providing advantages in allowing the operator to use different measurement devices with the same AACMM **100**. In one embodiment, the probe housing **102** houses a removable probe **118**, which is a contact measurement device and may have any number of different tips that physically contact the object to be measured, including, but not limited to, ball, touch-sensitive, curved, and extension type probes. In other embodiments, the measurement is performed, for example, by a non-contacting device such as a laser line probe (LLP). The handle **126** may be replaced with the LLP using a quick-connect interface. Other types of measurement devices may replace the removable handle **126** to provide additional functionality. Examples of

such measurement devices include, but are not limited to, one or more illumination lights, a bar code scanner, a projector, a paint sprayer, or a camera.

As shown in FIGS. **1A** and **1B** the AACMM **100** includes the removable handle that provides advantages in allowing accessories or functionality to be changed without removing the measurement probe housing **102** from the bearing cartridge grouping **112**. As discussed in more detail below, with respect to FIG. **2**, the removable handle may also include an electrical connector that allows electrical power and data to be exchanged with the handle and the corresponding electronics located in the probe end **401**.

In various embodiments, each grouping of bearing cartridges **110**, **112**, **114** allows the arm portion **104** of the AACMM **100** to move about multiple axes of rotation. As mentioned, each bearing cartridge grouping **110**, **112**, **114** includes corresponding encoder systems, such as optical angular encoders for example, that are each arranged coaxially with the corresponding axis of rotation of, e.g., the arm segments **106**, **108**. The optical encoder system detects rotational (swivel) or transverse (hinge) movement of, e.g., each one of the arm segments **106**, **108** about the corresponding axis and transmits a signal to an electronic data processing system within the AACMM **100** as described in more detail herein below. Each individual raw encoder count is sent separately to the electronic data processing system as a signal where it is further processed into measurement data. No position calculator separate from the AACMM **100** itself (e.g., a serial box) is required, as disclosed in commonly assigned U.S. Pat. No. 5,402,582 ('582).

The base **116** may include an attachment device or mounting device **120**. The mounting device **120** allows the AACMM **100** to be removably mounted to a desired location, such as an inspection table, a machining center, a wall or the floor for example. In one embodiment, the base **116** includes a handle portion **122** that provides a convenient location for the operator to hold the base **116** as the AACMM **100** is being moved. In one embodiment, the base **116** further includes a movable cover portion **124** that folds down to reveal a user interface, such as a display screen for example.

In accordance with an embodiment, the base **116** of the portable AACMM **100** contains or houses an electronic data processing system that includes two primary components: a base processing system that processes the data from the various encoder systems within the AACMM **100** as well as data representing other arm parameters to support three-dimensional (3-D) positional calculations; and a user interface processing system that includes an on-board operating system, a touch screen display, and resident application software that allows for relatively complete metrology functions to be implemented within the AACMM **100** without the need for connection to an external computer.

FIG. **2** is a block diagram of electronics utilized in an AACMM **100** in accordance with an embodiment. The embodiment shown in FIG. **2A** includes an electronic data processing system **210** including a base processor board **204** for implementing the base processing system, a user interface board **202**, a base power board **206** for providing power, a Bluetooth module **232**, and a base tilt board **208**. The user interface board **202** includes a computer processor for executing application software to perform user interface, display, and other functions described herein.

As shown in FIG. **2A**, the electronic data processing system **210** is in communication with the aforementioned plurality of encoder systems via one or more arm buses **218**. In the embodiment depicted in FIGS. **2B** and **2C**, each encoder system generates encoder data and includes: an encoder arm

bus interface **214**, an encoder digital signal processor (DSP) **216**, an encoder read head interface **234**, and a temperature sensor **212**. Other devices, such as strain sensors, may be attached to the arm bus **218**.

Also shown in FIG. 2D are probe end electronics **230** that are in communication with the arm bus **218**. The probe end electronics **230** include a probe end DSP **228**, a temperature sensor **212**, a handle/LLP interface bus **240** that connects with the handle **126** or the LLP **242** via the quick-connect interface in an embodiment, and a probe interface **226**. The quick-connect interface allows access by the handle **126** to the data bus, control lines, and power bus used by the LLP **242** and other accessories. In an embodiment, the probe end electronics **230** are located in the measurement probe housing **102** on the AACMM **100**. In an embodiment, the handle **126** may be removed from the quick-connect interface and measurement may be performed by the laser line probe (LLP) **242** communicating with the probe end electronics **230** of the AACMM **100** via the handle/LLP interface bus **240**. In an embodiment, the electronic data processing system **210** is located in the base **116** of the AACMM **100**, the probe end electronics **230** are located in the measurement probe housing **102** of the AACMM **100**, and the encoders are located in the bearing cartridge groupings **110**, **112**, **114**. The probe interface **226** may connect with the probe end DSP **228** by any suitable communications protocol, including commercially-available products from Maxim Integrated Products, Inc. that embody the 1-wire® communications protocol **236**.

FIG. 3 is a block diagram describing detailed features of the electronic data processing system **210** of the AACMM **100** in accordance with an embodiment. In an embodiment, the electronic data processing system **210** is located in the base **116** of the AACMM **100** and includes the base processor board **204**, the user interface board **202**, a base power board **206**, a Bluetooth module **232**, and a base tilt module **208**.

In an embodiment shown in FIG. 3A, the base processor board **204** includes the various functional blocks illustrated therein. For example, a base processor function **302** is utilized to support the collection of measurement data from the AACMM **100** and receives raw arm data (e.g., encoder system data) via the arm bus **218** and a bus control module function **308**. The memory function **304** stores programs and static arm configuration data. The base processor board **204** also includes an external hardware option port function **310** for communicating with any external hardware devices or accessories such as an LLP **242**. A real time clock (RTC) and log **306**, a battery pack interface (IF) **316**, and a diagnostic port **318** are also included in the functionality in an embodiment of the base processor board **204** depicted in FIG. 3.

The base processor board **204** also manages all the wired and wireless data communication with external (host computer) and internal (display processor **202**) devices. The base processor board **204** has the capability of communicating with an Ethernet network via an Ethernet function **320** (e.g., using a clock synchronization standard such as Institute of Electrical and Electronics Engineers (IEEE) 1588), with a wireless local area network (WLAN) via a LAN function **322**, and with Bluetooth module **232** via a parallel to serial communications (PSC) function **314**. The base processor board **204** also includes a connection to a universal serial bus (USB) device **312**.

The base processor board **204** transmits and collects raw measurement data (e.g., encoder system counts, temperature readings) for processing into measurement data without the need for any preprocessing, such as disclosed in the serial box of the aforementioned '582 patent. The base processor **204** sends the processed data to the display processor **328** on the

user interface board **202** via an RS485 interface (IF) **326**. In an embodiment, the base processor **204** also sends the raw measurement data to an external computer.

Turning now to the user interface board **202** in FIG. 3B, the angle and positional data received by the base processor is utilized by applications executing on the display processor **328** to provide an autonomous metrology system within the AACMM **100**. Applications may be executed on the display processor **328** to support functions such as, but not limited to: measurement of features, guidance and training graphics, remote diagnostics, temperature corrections, control of various operational features, connection to various networks, and display of measured objects. Along with the display processor **328** and a liquid crystal display (LCD) **338** (e.g., a touch screen LCD) user interface, the user interface board **202** includes several interface options including a secure digital (SD) card interface **330**, a memory **332**, a USB Host interface **334**, a diagnostic port **336**, a camera port **340**, an audio/video interface **342**, a dial-up/cell modem **344** and a global positioning system (GPS) port **346**.

The electronic data processing system **210** shown in FIG. 3A also includes a base power board **206** with an environmental recorder **362** for recording environmental data. The base power board **206** also provides power to the electronic data processing system **210** using an AC/DC converter **358** and a battery charger control **360**. The base power board **206** communicates with the base processor board **204** using integrated circuit (I2C) serial single ended bus **354** as well as via a DMA serial peripheral interface (DSPI) **35**. The base power board **206** is connected to a tilt sensor and radio frequency identification (RFID) module **208** via an input/output (I/O) expansion function **364** implemented in the base power board **206**.

Though shown as separate components, in other embodiments all or a subset of the components may be physically located in different locations and/or functions combined in different manners than that shown in FIG. 3. For example, in one embodiment, the base processor board **204** and the user interface board **202** are combined into one physical board.

Referring now to FIGS. 4 and 5, an exemplary arm segment **108** of arm **104** of the AACMM **100** is illustrated in more detail. Each arm segment **106**, **108** includes a generally cylindrical hollow core **500** made from a suitably rigid material such as, but not limited to, a carbon-fiber composite material for example. A carbon-fiber composite material may be selected because of its low coefficient of thermal expansion (CTE) and its high stiffness. The core may alternatively be made from an extruded or woven synthetic material or metal. In one embodiment, the tubular core **500** of each arm segment **106**, **108** is manufactured by wrapping at least one layer of an impregnated carbon-fiber composite material around a mandrel rotatable about a longitudinal axis X. In other embodiments, the core **500** may be made by other materials such as but not limited to extrude or woven synthetic materials or metals.

An outer material **550** is positioned adjacent the exterior surface **506** of the core **500** to enhance the aesthetic appeal of each arm segment **106**, **108**. The outer material **550** may include at least one layer of a composite material, such as an aluminum coated glass fiber epoxy prepreg for example. In one embodiment, the outer material **550** is Texalium® manufactured by Hexcel Corporation. In some embodiments, the absolute value of the coefficient of thermal expansion (CTE) of the material in the outer layer is much larger than the CTE of the composite material of the inner core **500**. FIGS. 6 and 7 show the composition of the outer material **550** in detail. The outer material **550** includes a plurality of first fibers **560**

oriented in a first direction and a plurality of second fibers **562** oriented in a second, different direction. In one embodiment, the first direction and the second direction are orthogonal to one another. The fibers **560**, **562** of each layer of the outer material **550** may be arranged in any number of orientations, including but not limited to, a woven configuration, a braided configuration, or a unidirectional configuration for example. In one embodiment, one of the plurality of first fibers **560** and the plurality of second fibers **562** of the outer material **550** is oriented generally coaxially with the longitudinal axis X (see FIG. 6). In such embodiments, the other of the plurality of first fibers **560** and the plurality of second fibers **562** is oriented cylindrically, such that the fibers extend in a direction around the periphery of the tubular outer material **550** and the longitudinal axis X. In another embodiment, illustrated in FIG. 7, the plurality of first fibers **560** and the plurality of second fibers **562** may be arranged such that both the first fibers **560** and the second fibers **562** are oriented at a generally 45 degree angle to the longitudinal axis X.

The cross-section of exemplary arm segment **108**, illustrated in FIG. 4, is formed by wrapping the outer material **550** around the carbon fiber core **500**, for instance before the core **500** is removed from the mandrel. In a first embodiment, outer material **550** is bonded to the outer surface **506** of the core **500** by applying pressure from a vacuum and heat to the arm segment **108**. The outer material **550** is wrapped around the core **500** such that the plurality of first fibers **560** and the plurality of second fibers **562** are in a desired orientation relative to each other and to the longitudinal axis X. By arranging the fibers **560**, **562** in the outer material **550** orthogonally and by orienting them relative to the longitudinal axis X the torsional effects are minimized and restricted. As such, the outer material **550** is less likely to twist relative to the core **500** in response to a temperature change. The resulting torque placed on the encoders **214**, **216**, **234** of the arm **104** due to a change in environmental temperature is reduced or eliminated, thus improving the accuracy of the AACMM **100**.

As shown in FIG. 8, the outer material **550** may alternatively be formed as a separate component **570**, such as a tubular sleeve or shell for example, that slidably engages the core **500**. The sleeve **570** may extend over a portion of, or alternatively, over the entire length of an inner core **500**. In embodiments where the outer material **550** is a sleeve **570**, the external surface **506** of the core **500** is smoothed, giving the core **500** a uniform outer diameter. The outer material sleeve **570** has an inner diameter larger than the outer diameter of the core **500** to create a loose fit. The outer material sleeve **570** may include a first portion **574** adjacent a first end **572** and a second portion **576** extending from the first portion **574** to adjacent a second, opposite end **578**. In one embodiment, the first portion **574** of the sleeve **570** is coupled to a first end **502** of the core **500** (see FIG. 5) and the second portion **576** of the sleeve **570** is configured to move freely relative to the core **500** (see FIG. 9). By coupling only the first portion **574** of the sleeve **570** to the core **500**, torsional forces from the sleeve **570** are imparted to the core **500** only at the location where the sleeve **570** and core **500** are coupled, rather than over the full length of the core **500**. In one embodiment, the sleeve **570** is coupled to the end **502** of the core **500** opposite, not adjacent, a bearing cartridge **110**, **112**, **114**. The first portion **574** of the sleeve **570** may be coupled to the first end **502** of the core **500** such as with a fastener, a weld, an adhesive, diffusion bonding, ultrasonic welding or any other known connection means. In one embodiment, the first portion **574** extends a predetermined length from the end **572** of the sleeve **570** wherein the first portion **574** is substantially smaller than the

remaining portion of the sleeve **570**. In the embodiment of FIG. 1, the sleeve **570** on arm segment **108** is coupled to the composite core of the arm segment **108** near the bearing cartridge pair **112**. The sleeve on the arm segment **106** is coupled to the composite core of the arm segment **106** near the bearing cartridge pair **110**. The short segment **107** has an outer sleeve that covers a metallic element such as aluminum or steel. It should be appreciated that the location of the coupling of the sleeve **570** to the core **500** may be reversed or a combination thereof.

Forming the outer material **550** as a sleeve **570** separate from the core **500** further isolates the core **500** of an arm segment **106**, **108** from the twisting of the outer material **550** caused by a non-orthogonal fiber orientation. The sleeve **570** also isolates the core **500** from torque induced by a user while operating the AACMM **100**, thereby further improving the accuracy of the machine. In addition, the sleeve **570** may be removably connected to the core **500** to allow for easy replacement if the outer material sleeve **570** is damaged. The color of the sleeve **570** may also be modified to correlate with a desired model of the AACMM **100**.

While the invention has been described with reference to example embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another.

Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

What is claimed is:

1. A portable articulated arm coordinate measurement machine (AACMM), comprising:
 - a manually positionable articulated arm having opposed first and second ends, the arm including a plurality of connected arm segments, at least one of the arm segments having a longitudinal axis and including:
 - a generally tubular composite core; and
 - an outer sleeve surrounding at least a portion of the composite core, wherein the outer sleeve is a cylindrical tube including an integrally formed first portion and second portion, the first portion being arranged adjacent a first end of the outer sleeve and the second portion extending between the first portion and a second, opposite end of the outer sleeve, the first portion is being affixed to an end of the composite core and having a shorter length than the second portion and wherein the second portion is configured to move relative to the composite core;
 - a measurement device attached to a first end of the AACMM; and
 - an electronic circuit for providing data corresponding to a position of the measurement device.
2. The portable AACMM according to claim 1, wherein the composite core includes a carbon fiber composite.
3. The portable AACMM according to claim 2, wherein the composite core includes eleven layers.

4. The portable AACMM according to claim 1, wherein the first portion of the outer sleeve is coupled to the end of the composite core with an adhesive.

5. The portable AACMM according to claim 1, wherein the outer sleeve surrounds an entire length of the composite core.

6. The portable AACMM according to claim 1, wherein the outer sleeve is made from a composite including aluminum coated glass fiber epoxy prepreg.

7. The portable AACMM according to claim 6, wherein the outer sleeve includes two layers.

8. The portable AACMM according to claim 6, wherein the outer sleeve includes a plurality of first fibers arranged substantially orthogonal to a plurality of second fibers.

9. The portable AACMM according to claim 8, wherein the plurality of first fibers and the plurality of second fibers are oriented at about a 45 degree angle to the longitudinal axis.

10. The portable AACMM according to claim 8, wherein the plurality of first fibers is oriented substantially parallel to the longitudinal axis.

11. The portable AACMM according to claim 10, wherein the plurality of second fibers is oriented substantially cylindrically about the outer sleeve.

12. A portable articulated arm coordinate measurement machine (AACMM), comprising:

a manually positionable articulated arm having opposed first and second ends, the arm including a plurality of connected arm segments, at least one of the arm segments having a longitudinal axis and including:

a composite core;

an outer sleeve configured to surround the composite core, an absolute coefficient of thermal expansion of the outer sleeve being larger than an absolute coefficient of thermal expansion of the core wherein the outer sleeve includes a plurality of first fibers arranged substantially orthogonal to a plurality of second fibers, wherein and the plurality of first fibers and the plurality of second fibers are arranged relative to a longitudinal axis of the arm segment;

a measurement device attached to a first end of the AACMM; and

an electronic circuit for providing data corresponding to a position of the measurement device.

13. The portable AACMM according to claim 12, wherein the plurality of first fibers and the plurality of second fibers are oriented at about a 45 degree angle to the longitudinal axis.

14. The portable AACMM according to claim 12, wherein the plurality of first fibers is oriented substantially parallel to the longitudinal axis.

15. The portable AACMM according to claim 14, wherein the plurality of second fibers is oriented substantially cylindrically about the longitudinal axis.

16. The portable AACMM according to claim 12, wherein the outer sleeve is a composite including aluminum coated glass fiber epoxy prepreg.

17. The portable AACMM according to claim 16, wherein the outer sleeve includes two layers of fibers.

18. The portable AACMM according to claim 12, wherein the outer sleeve includes a first portion and a second portion and the first portion is coupled to an end of the composite core.

19. The portable AACMM according to claim 18, wherein the outer sleeve is coupled to the end of the composite core using an adhesive.

20. The portable AACMM according to claim 12, wherein the composite core includes a carbon fiber composite.

21. The portable AACMM according to claim 12, wherein the composite core includes a plurality of third fibers oriented substantially orthogonal to a plurality of fourth fibers.

22. A method of forming an arm segment for a portable AACMM, comprising:

forming a generally hollow cylindrical core having a longitudinal axis from a first material;

forming a tubular sleeve from a second material having a plurality of first fibers arranged orthogonally to a plurality of second fibers such that the plurality of first fibers and the plurality of second fibers are in a desired orientation relative to the axis, the sleeve including an integrally formed first portion and second portion;

inserting the core into the sleeve; and

affixing a first portion of the sleeve to a first end of the core such that the second portion of the sleeve is movable relative to the core.

23. The method according to claim 22, wherein the first portion of the sleeve is affixed to the first end of the core using an adhesive.

24. The method according to claim 22, wherein the plurality of first fibers is oriented substantially parallel to the axis and the plurality of second fibers is oriented substantially cylindrically about the axis.

25. The method according to claim 22, wherein the plurality of first fibers and the plurality of second fibers are oriented at about a 45 degree angle to the axis.

26. The method according to claim 22, wherein the core includes a carbon fiber composite.

* * * * *